Complete Summary

GUIDELINE TITLE

Metabolic measurement using indirect calorimetry during mechanical ventilation — 2004 revision & update.

BIBLIOGRAPHIC SOURCE(S)

American Association for Respiratory Care. Metabolic measurement using indirect calorimetry during mechanical ventilation--2004 revision & update. Respir Care 2004 Sep;49(9):1073-9. [84 references]

GUIDELINE STATUS

This is the current release of the guideline.

This guideline updates a previous version: American Association for Respiratory Care (AARC). AARC clinical practice guideline. Metabolic measurement using indirect calorimetry during mechanical ventilation. Respir Care 1994 Dec;39(12):1170-5.

COMPLETE SUMMARY CONTENT

SCOPE

DISEASE/CONDITION(S)

- Pulmonary disease
- Nutritional risk, deficit, or derangement

GUIDELINE CATEGORY

Assessment of Therapeutic Effectiveness

CLINICAL SPECIALTY

Nutrition
Pediatrics
Pulmonary Medicine

INTENDED USERS

Respiratory Care Practitioners

GUIDELINE OBJECTIVE(S)

- To improve the consistency and appropriateness of respiratory care and serve as a guide for education and research
- To provide clinical practice guidelines addressing metabolic measurement during mechanical ventilation

TARGET POPULATION

Mechanically ventilated neonatal, pediatric, and adult patients in the hospital or in extended care facilities

INTERVENTIONS AND PRACTICES CONSIDERED

Metabolic measurements using indirect calorimetry for determination of oxygen consumption (V_{O2}), carbon dioxide production (V_{CO2}), respiratory quotient (RQ), and resting energy expenditure (REE)

MAJOR OUTCOMES CONSIDERED

- Resting energy expenditure (REE) measurements
- Incidence of overfeeding and underfeeding
- Costs associated with total parenteral nutrition

METHODOLOGY

METHODS USED TO COLLECT/SELECT EVIDENCE

Searches of Electronic Databases

DESCRIPTION OF METHODS USED TO COLLECT/SELECT THE EVIDENCE

Not stated

NUMBER OF SOURCE DOCUMENTS

Not stated

METHODS USED TO ASSESS THE QUALITY AND STRENGTH OF THE EVIDENCE

Not stated

RATING SCHEME FOR THE STRENGTH OF THE EVIDENCE

Not applicable

METHODS USED TO ANALYZE THE EVIDENCE

Systematic Review

DESCRIPTION OF THE METHODS USED TO ANALYZE THE EVIDENCE

Not stated

METHODS USED TO FORMULATE THE RECOMMENDATIONS

Not stated

RATING SCHEME FOR THE STRENGTH OF THE RECOMMENDATIONS

Not applicable

COST ANALYSIS

A formal cost analysis was not performed and published cost analyses were not reviewed.

METHOD OF GUIDELINE VALIDATION

External Peer Review
Internal Peer Review

DESCRIPTION OF METHOD OF GUIDELINE VALIDATION

Consultants to the Working Group may review the initial draft of the guideline. After completion by the Working Group, the draft is reviewed by the entire Steering Committee and then by a Review Panel (i.e., persons engaged in all facets of the delivery of respiratory care who have volunteered to review drafts of the Guidelines before publication).

This update was approved by the 2003 Clinical Practice Guideline (CPG) Steering Committee.

RECOMMENDATIONS

MAJOR RECOMMENDATIONS

Procedure

Metabolic measurements using indirect calorimetry for determination of oxygen consumption (V_{O2}), carbon dioxide production (V_{CO2}), respiratory quotient (RQ), and resting energy expenditure (REE) as an aid to patient nutritional assessment and management; assessment of weaning success and outcome; assessment of the relationship between O_2 delivery (D_{O2}) and V_{O2}; and assessment of the contribution of metabolism to ventilation. The guideline addresses metabolic measurement during mechanical ventilation.

Description/Definition

Metabolic measurements use an indirect calorimeter to measure V_{O2} and V_{CO2} via expired gas analysis. The measurements of V_{O2} and V_{CO2} are used to calculate RQ (V_{CO2}/V_{O2}) and REE using the Weir equation:

$$REE = [V_{O2} (3.941) + V_{CO2} (1.11)] 1440 \text{ min/day}$$

The measurement of REE in mechanically ventilated neonatal, pediatric, and adult patients has been shown to be more accurate than published formulas used to predict REE, to reduce the incidence of overfeeding and underfeeding, and to decrease costs associated with total parenteral nutrition (TPN). Measurement of REE and RQ has been shown to be helpful in designing nutritional regimens to reduce V_{CO2} in patients with chronic obstructive pulmonary disease (COPD) and patients requiring mechanical ventilation. Despite this evidence, studies demonstrating improved outcome, decreased time spent on the ventilator, or shorter intensive care unit (ICU)/hospital stay are lacking.

The objectives of metabolic measurements by indirect calorimetry are:

- To accurately determine the REE of mechanically ventilated patients to guide appropriate nutritional support
- To accurately determine RQ to allow nutritional regimens to be tailored to patient needs
- To accurately determine REE and RQ to monitor the adequacy and appropriateness of current nutritional support
- To allow determination of substrate utilization when urinary nitrogen values are concomitantly measured
- To determine the O_2 cost of breathing as a guide to the selection of ventilator mode, settings, and weaning strategies
- To monitor the V_{O2} as a guide to targeting adequate D_{O2}
- To assess the contribution of metabolism to ventilation

Setting

- Mechanically ventilated patients
    - In the hospital
    - In the extended care facility

Indications

Metabolic measurements may be indicated:

- In patients with known nutritional deficits or derangements. Multiple nutritional risk and stress factors that may considerably skew prediction by Harris-Benedict equation include:
    - Neurologic trauma
    - Paralysis
    - COPD
    - Acute pancreatitis
    - Cancer with residual tumor burden
    - Multiple trauma
    - Amputations
    - Patients in whom height and weight cannot be accurately obtained
    - Patients who fail to respond adequately to estimated nutritional needs
    - Patients who require long-term acute care
    - Severe sepsis
    - Extremely obese patients
    - Severely hypermetabolic or hypometabolic patients
- When patients fail attempts at liberation from mechanical ventilation to measure the O_2 cost of breathing and the components of ventilation
- When the need exists to assess the V_{O2} in order to evaluate the hemodynamic support of mechanically ventilated patients
- To measure cardiac output by the Fick method
- To determine the cause(s) of increased ventilatory requirements

Contraindications

Refer to the "Contraindications" field or see the original guideline document.

Hazards/Complications

Refer to the "Potential Harms" field or see the original guideline document.

Limitations of Procedure

Limitations of the procedure include:

- Accurate assessment of REE and RQ may not be possible because of patient condition or certain bedside procedures or activities.
- Inaccurate measurement of REE and RQ may be caused by leaks of gas from the patient/ventilator system preventing collection of expired gases including:
    - Leaks in the ventilator circuit
    - Leaks around tracheal tube cuffs or uncuffed tubes
    - Leaks through chest tubes or bronchopleural fistula
- Inaccurate measurement of REE and RQ occurs during peritoneal and hemodialysis due to removal across the membrane of CO_2 that is not measured by the indirect calorimeter.
- Inaccurate measurement of REE and RQ during open circuit measurement may be caused by:
    - Instability of delivered oxygen concentration (F_{IO2}) within a breath or breath to breath due to changes in source gas pressure and ventilator blender/mixing characteristics

    - F_{IO2} >0.60
    - Inability to separate inspired and expired gases due to bias flow from flow-triggering systems, IMV systems, or specific ventilator characteristics
    - The presence of anesthetic gases or gases other than O_2, CO_2, and nitrogen in the ventilation system
    - The presence of water vapor resulting in sensor malfunction
    - Inappropriate calibration
    - Connection of the indirect calorimeter to certain ventilators, with adverse effect on triggering mechanism, increased expiratory resistance, pressure measurement, or maintenance of the ventilator
    - Total circuit flow exceeding internal gas flow of indirect calorimeter that incorporates the dilutional principle
    - Internal leaks within the calorimeter
    - Inadequate length of measurement
- Inaccurate measurement of REE and RQ during closed circuit measurement may be caused by:
    - Short duration of the measurement period (a function of CO_2 absorber life and V_{CO2}) that may not allow REE state to be achieved
    - Changes in functional residual capacity (FRC) resulting in changes in spirometer volume unassociated with V_{O2}
    - Leaks drawing gas into the system during spontaneous breathing measurements that adds volume to the system and cause erroneously low V_{O2} readings
    - Increased compressible volume in the circuit that prevents adequate tidal volume delivery resulting in alveolar hypoventilation and changes in V_{CO2}/V_{O2}
    - Increased compressible volume and resistance that results in difficulty triggering the ventilator and increased work of breathing

Assessment of Need

Metabolic measurements should be performed only on the order of a physician after review of indications (see "Indications" section above) and objectives.

Assessment of Test Quality and Outcome

Test quality can be evaluated by determining whether:

- RQ is consistent with the patient's nutritional intake
- RQ rests in the normal physiologic range (0.67 to 1.3)
- Variability of the measurements for V_{O2} and V_{CO2} should be $\leq$5% for a 5-minute data collection
- The measurement is of sufficient length to account for variability in V_{O2} and V_{CO2} if the above conditions ($\leq$5% for a 5-minute data collection) are not met

Outcome may be assessed by comparing the measurement results with the patient's condition and nutritional intake.

Outcome may be assessed by observation of the patient prior to and during the measurement to determine if the patient is at steady state.

Resources

Indirect calorimeter, open- or closed-circuit design:

- The calibration gas mixture should be relevant to the concentration of gas to be measured clinically.
- The indirect calorimeter should be calibrated on the day of measurement and more often if errors in measurement are suspected.
- When the measurement results are suspect and/or when repeated calibration attempts are marked by instability, the indirect calorimeter may be tested via an independent test method (burning ethanol or other substance with a known RQ or adding known flows of CO_2 and nitrogen to simulate V_{O2} and V_{CO2}). As a simple test, ventilation of a leak-free system should yield V_{O2} and V_{CO2} values of near 0. Routinely scheduled measurement of normal control subjects (volunteers) may be useful.

A method of stabilizing F_{IO2} during open-circuit measurements should be available and may include:

- An air-oxygen blender connected between the gas source and the ventilator inlets for high pressure gas
- An inspiratory mixing chamber between the ventilator main flow circuit and the humidifier (see "Hazards/Complications" in "Potential Harms" field or refer to original guideline document)
- Ventilator changes, which may include mode, inspiratory flow rate, positive end-expiratory pressure (PEEP), or tidal volume to improve patient-ventilator synchrony

An isolation valve, double-piloted exhalation valve, or other device to separate inspiratory and expiratory flow should be incorporated when using continuous flow in the ventilator circuit (see "Hazards/Complications" in "Potential Harms" field or refer to original guideline document).

Personnel: Due to the level of technical and patient assessment skills required, metabolic measurements using indirect calorimeters should be performed by individuals trained in and with the demonstrated and documented ability to:

- Calibrate, operate, and maintain an indirect calorimeter
- Operate a mechanical ventilator, including knowledge of the air-oxygen blending system, the spontaneous breathing mechanisms, and the alarm and monitoring functions
- Recognize metabolic measurement values within the normal physiologic range and evaluate the results in light of the patient's current nutritional and clinical status
- Assess patient hemodynamic and ventilatory status and make recommendations on appropriate corrective/therapeutic maneuvers to improve or reverse the patient's clinical course. A relevant credential (e.g., RRT, CRT, RN, or RPFT) is desirable.

A hood canopy system in combination with airway sampling may be employed to capture gas that leaks around an uncuffed endotracheal tube.

If a stable F_{IO2} cannot be achieved, V_{CO2} may be used to estimate REE by assuming an RQ of 0.83 and the largest expected error is an:

- Underestimation of 25% for RQ of 1.2
- Overestimation of 19% for RQ of 0.67

A simultaneous measure of P_{aCO2} and V_{CO2} will allow calculation of pulmonary dead space and components of ventilation using the Bohr equation:

$V_E = V_{CO2} \times 0.863\ P_{aCO2} \times (1-V_D/V_T)$

Monitoring

The following should be evaluated during the performance of a metabolic measurement to ascertain the validity of the results:

- Clinical observation of the resting state (see "Assessment of Test Quality and Outcome" section above)
- Patient comfort and movement during testing
- Values in concert with the clinical situation
- Equipment function
- Results within the specifications listed in "Assessment of Test Quality and Outcome" section above
- F_{IO2} stability

Measurement data should include a statement of test quality and list the current nutritional support, ventilator settings, F_{IO2} stability, and vital signs.

Frequency

Metabolic measurements should be repeated according to the clinical status of the patient and indications for performing the test. The literature suggests that more frequent measurement may be necessary in patients with a rapidly changing clinical course as recognized by:

- Hemodynamic instability
- Spiking fevers

Patients in the immediate postoperative period and those being weaned from mechanical ventilation may also need more frequent measurement.

Infection Control

Metabolic measurements using indirect calorimetry are relatively safe procedures, but a remote possibility of cross-contamination exists either via patient-patient or patient-caregiver interface. The following guidelines should be followed when a metabolic measurement is performed.

- Standard Precautions should be exercised whenever there is potential for contamination with blood or other body fluids.
- Appropriate use of barriers and hand washing is recommended.

- Tubing used to direct expiratory gas from the ventilator to the indirect calorimeter should be disposed of or cleaned between patients.
- Connections used in the inspiratory limb of the circuit proximal to the humidifier should be wiped clean between patients; equipment distal to the humidifier should be disposed of or subjected to high-level disinfection between patients.
- Bacteria filters may be used to protect equipment in both the inspired and expired lines, but caution should be used that moisture does not increase filter resistance resulting in poor gas sampling flow or increased resistance to exhalation.

CLINICAL ALGORITHM(S)

None provided

EVIDENCE SUPPORTING THE RECOMMENDATIONS

TYPE OF EVIDENCE SUPPORTING THE RECOMMENDATIONS

The type of supporting evidence is not specifically stated for each recommendation.

BENEFITS/HARMS OF IMPLEMENTING THE GUIDELINE RECOMMENDATIONS

POTENTIAL BENEFITS

- Accurate metabolic measurement during mechanical ventilation
- Improved nutritional support for mechanically ventilated patients

POTENTIAL HARMS

Performing metabolic measurements using an indirect calorimeter is a safe, noninvasive procedure with few hazards or complications. Under certain circumstances and with particular equipment the following hazards/complications may be seen.

- Closed circuit calorimeters may cause a reduction in alveolar ventilation due to increased compressible volume of the breathing circuit.
- Closed circuit calorimeters may decrease the trigger sensitivity of the ventilator and result in increased patient work of breathing.
- Short-term disconnection of the patient from the ventilator for connection of the indirect calorimetry apparatus may result in hypoxemia, bradycardia, and patient discomfort.
- Inappropriate calibration or system setup may result in erroneous results causing incorrect patient management.
- Isolation valves may increase circuit resistance and cause increased work of breathing and/or dynamic hyperinflation.
- Inspiratory reservoirs may cause a reduction in alveolar ventilation due to increased compressible volume of the breathing circuit.

- Manipulation of the ventilator circuit may cause leaks that may lower alveolar ventilation.

CONTRAINDICATIONS

CONTRAINDICATIONS

When a specific indication is present, there are no contraindications to performing a metabolic measurement using indirect calorimetry unless short-term disconnection of ventilatory support for connection of measurement lines results in hypoxemia, bradycardia, or other adverse effects.

QUALIFYING STATEMENTS

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The measurement of resting energy expenditure (REE) in mechanically ventilated neonatal, pediatric, and adult patients has been shown to be more accurate than published formulas used to predict REE, to reduce the incidence of overfeeding and underfeeding, and to decrease costs associated with total parenteral nutrition (TPN). Measurement of REE and respiratory quotients (RQ) has been shown to be helpful in designing nutritional regimens to reduce carbon dioxide production (V_{CO2}) in patients with chronic obstructive pulmonary disease (COPD) and patients requiring mechanical ventilation. Despite this evidence, studies demonstrating improved outcome, decreased time spent on the ventilator, or shorter intensive care unit/hospital stay are lacking.

IMPLEMENTATION OF THE GUIDELINE

DESCRIPTION OF IMPLEMENTATION STRATEGY

An implementation strategy was not provided.

INSTITUTE OF MEDICINE (IOM) NATIONAL HEALTHCARE QUALITY REPORT CATEGORIES

IOM CARE NEED

Getting Better
Living with Illness

IOM DOMAIN

Effectiveness
Safety

IDENTIFYING INFORMATION AND AVAILABILITY

BIBLIOGRAPHIC SOURCE(S)

American Association for Respiratory Care. Metabolic measurement using indirect calorimetry during mechanical ventilation--2004 revision & update. Respir Care 2004 Sep;49(9):1073-9. [84 references]

ADAPTATION

Not applicable: The guideline was not adapted from another source.

DATE RELEASED

1994 Dec (revised 2004 Sep)

GUIDELINE DEVELOPER(S)

American Association for Respiratory Care - Professional Association

SOURCE(S) OF FUNDING

American Association for Respiratory Care (AARC)

GUIDELINE COMMITTEE

Not stated

COMPOSITION OF GROUP THAT AUTHORED THE GUIDELINE

Primary Author: Charles D. McArthur, RRT, RPFT, Immanuel St Joseph's - Mayo Health System, Mankato, Minnesota

FINANCIAL DISCLOSURES/CONFLICTS OF INTEREST

Not stated

GUIDELINE STATUS

This is the current release of the guideline.

This guideline updates a previous version: American Association for Respiratory Care (AARC). AARC clinical practice guideline. Metabolic measurement using indirect calorimetry during mechanical ventilation. Respir Care 1994 Dec;39(12):1170-5.

GUIDELINE AVAILABILITY

Electronic copies: Available in Portable Document Format (PDF) from the American Association for Respiratory Care (AARC) Web site.

Print copies: Available from the American Association for Respiratory Care (AARC), CPG Desk, 11030 Ables Ln, Dallas, TX 75229-4593; Web site: www.aarc.org.

AVAILABILITY OF COMPANION DOCUMENTS

None available

PATIENT RESOURCES

None available

NGC STATUS

This summary was completed by ECRI on November 30, 1998. The information was verified by the guideline developer on December 15, 1998. This NGC summary was updated by ECRI on March 22, 2005.

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